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THE DESIGN AND OPERATION OF A PARALLEL STIFF COMPRESSION APPARATUS

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THE DESIGN AND OPERATION OF A PARALLEL STIFF COMPRESSION APPARATUS

by

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ABSTRACT

The equipment described in this report allows complete stress-strain testing of rock specimens in compression including residual strength characteristics. Varying sample diameters may also be accommodated in the triaxial state with this equipment. The assembly basically acts as a parallel element to stiffen the existing compression apparatus.

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CONCEPTION ET MODE DE FONCTIONNEMENT D'UN COMPRESSEUR PARALLÈLE DE RENFORCEMENT

par

B. Gorski*

RÉSUMÉ

L'équipement décrit dans ce rapport permet des essais de résistance complets, y compris des caractéristiques de résistance résiduelle, des échantillons de roche à la compression. On peut aussi faire le contrôle d'échantillons de diamètres variés à l'état triaxial. Le montage est essentiellement un élément parallèle servant à renforcer le compresseur en usage.

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INTRODUCTION

Equipment designed by Shimotant et al. has been used successfully for determining the complete stress-strain behaviour of 'BX' cores of both hard and soft rock types in the Rock Mechanics Laboratory [1,2,3]. The method of uniaxial or triaxial testing involved the loading of rock specimens in parallel with pre-engineered disc springs. The design and operation of this apparatus is described in detail by B. Gorski [4].

Additional test requirements have necessitated the development of a larger test apparatus to accommodate rock specimen diameters varying from 'BX' to 'NX' size under uniaxial or triaxial test conditions.

In this report, testing procedures and special design features of the 'NX' stiff triaxial assembly are presented including selected test results.

DESIGN CONSIDERATIONS

The recently acquired 'NX' stiff assembly has successfully been used for one test program [5]. The assembly is presently being used in assessing rock properties of core originating from the Donkin-Morien tunnel site. The 'NX' stiff assembly has several distinct design features over the 'BX' assembly as follows:

1. The upper half of the stiff assembly is attached to the press crosshead, thereby allowing the system to be raised and lowered into position mechanically, instead of by a manual method.
2. The strain-gauged load cell is bolted in place and protected by a shroud.
3. The ten disc springs are bolted in place as a unit by incorporating a collar and upper plate with the shroud.
4. The support system accommodates an 'NX' Hoek cell assembly.
5. The larger disc springs allow additional axial displacement during testing.
6. High-chrome tool-steel inserts have been incorporated to reduce indentation effects under load.

DESIGN AND CONSTRUCTION

PRINCIPLE OF OPERATION

Figure 1 depicts the 'NX' stiff assembly set-up for a triaxial test. The entire assembly is set-up in a medium capacity testing machine ("soft"

press). Figure 2 depicts the apparatus in place in readiness for a uniaxial test.

The load applied to the upper plate causes the springs to deflect as the shroud and load cell transmit axial load to the rock specimen. Load carried by the disc springs is transmitted to the lower plate via the support. In this way press load is shared by the disc springs and the test specimen. The deflection of disc springs is linear with the applied load. The stiffness of the press can be proportionally varied by the number of disc springs used.

HOIST CLIPS

The hoist clips facilitate the clamping of the upper half of the stiff assembly to the press crosshead platen. This process eliminates manual setup of the heavy upper half which is now raised and lowered in place mechanically through the operation of the crosshead. Figure 1 shows that the upper plate, disc springs, shroud, collar and load cell are held together, as a unit, by means of a cap screw and a high-strength bolt.

DISC SPRINGS

Ten Schnorr disc springs were selected as the stiffening element in this assembly. The springs are stacked in parallel. Each disc is 16 mm thick with outside and inside diameters of 250 mm and 127 mm, respectively. The deflection characteristics of the ten springs and the support, in function of applied load, are depicted in Fig. 3.

The stiffness of the system in the higher load range can be readily calculated which is in the order of 0.77 GN/m. During an actual test, the initial low stiffness of the springs is suppressed by a sufficiently high pre-load. It is applied to the springs prior to load contact with the sample.

FERRO-TIC INSERTS

Assembly locations subjected to high stresses now have high-chrome tool-steel inserts. The stiffness of these inserts is approximately 1.5 times that of mild steel, thereby considerably reducing indentation deflections during testing.

LOAD CELL

The load cell is housed and bolted inside a steel shroud, to minimize the possibility of damage or environmental effects to the bonded strain gauges. The gauges comprise a full bridge configuration to maximize the sensitivity and, at the same time, are self temperature compensating. The load cell monitors the true axial load acting on the rock specimen, regardless of the load taken up by the disc springs.

'NX' HOEK CELL

For triaxial tests an 'NX' Hock cell is used. To date, samples varying in diameter from 38 mm to 54 mm have been tested using this Hoek cell. Samples considerably less than 54 mm in diameter are accommodated by using spacer jackets. The split jackets are constructed in-house, using compressor hose.

A minor modification of the Hoek cell became necessary to increase the platen-end cap clearance. It was achieved by machine turning the internal diameter of the caps. Extrusion of the urethane jacket through this new clearance was not of concern during testing because the Hoek cell is only used up to one half of its rated capacity. This new clearance facilitated easier feed through of strain gage leads from the rock specimen. The possibility of leads shorting out during testing was also reduced.

SERVO-VALVE

To arrest rock failure during post-failure tests, a push button, connected electrically to a magneto-electric valve, is used. The valve, developed by F. Kapeller of CANMET, opens and shuts the hydraulic by-pass of the compression testing machine. In this way partial unloading of the rock sample can be readily accomplished. Figure 4 depicts a complete stress-strain plot obtained for Indiana limestone, tested for uniaxial strength. During testing the slope of the line plotting axial load versus sample axial deformation is monitored visually. The onset of sample failure is indicated by non linear plotting. At this point in time the button is pushed to arrest rock failure. The amount of load removed from the sample need not be more than 20% of total. The load is then allowed to increase on the sample and the above procedure is repeated. The procedure is repeated continuously until the complete post failure rock strength is obtained.

ACCESSORY EQUIPMENT

Additional equipment required to complete a post-failure triaxial test are described in reference [4]. Briefly, they comprise the following:

- 3 B&K strain indicators
- 2 X, Y_1, Y_2 recorders
- 1 analog output confinement pressure indicator
- 2 LVDTS (linear variable differential transducers)
- 1 compression machine
- 1 confinement pressure panel.

TYPICAL TEST DATA

Figure 4 shows a stress-strain plot for a uniaxial compressive strength test conducted on Indiana limestone. The post-failure part of the plot was obtained by cycling the load as previously described. The plot depicts a Class I failure [6] mode, having residual strength. Figure 5 depicts plots of press load versus sample load and press load versus disc spring displacement obtained while testing the rock specimen which resulted in the stress-strain relationship shown in Fig. 4. Figure 5 indicates that in the post-failure region the loss of load carrying capacity of the sample is non-linear. However, at the same time the springs respond linearly under increasing load.

SUMMARY AND CONCLUSIONS

The 'NX' stiff triaxial assembly is presently being used in assessing strength characteristics of rock core originating from the Donkin-Morien tunnel site. The multiple failure state method is being used and post-failure data including residual strengths are being obtained. Rock specimens of 38 mm diameter are being tested successfully in the triaxial state using the 'NX' Hoek cell and spacer jackets.

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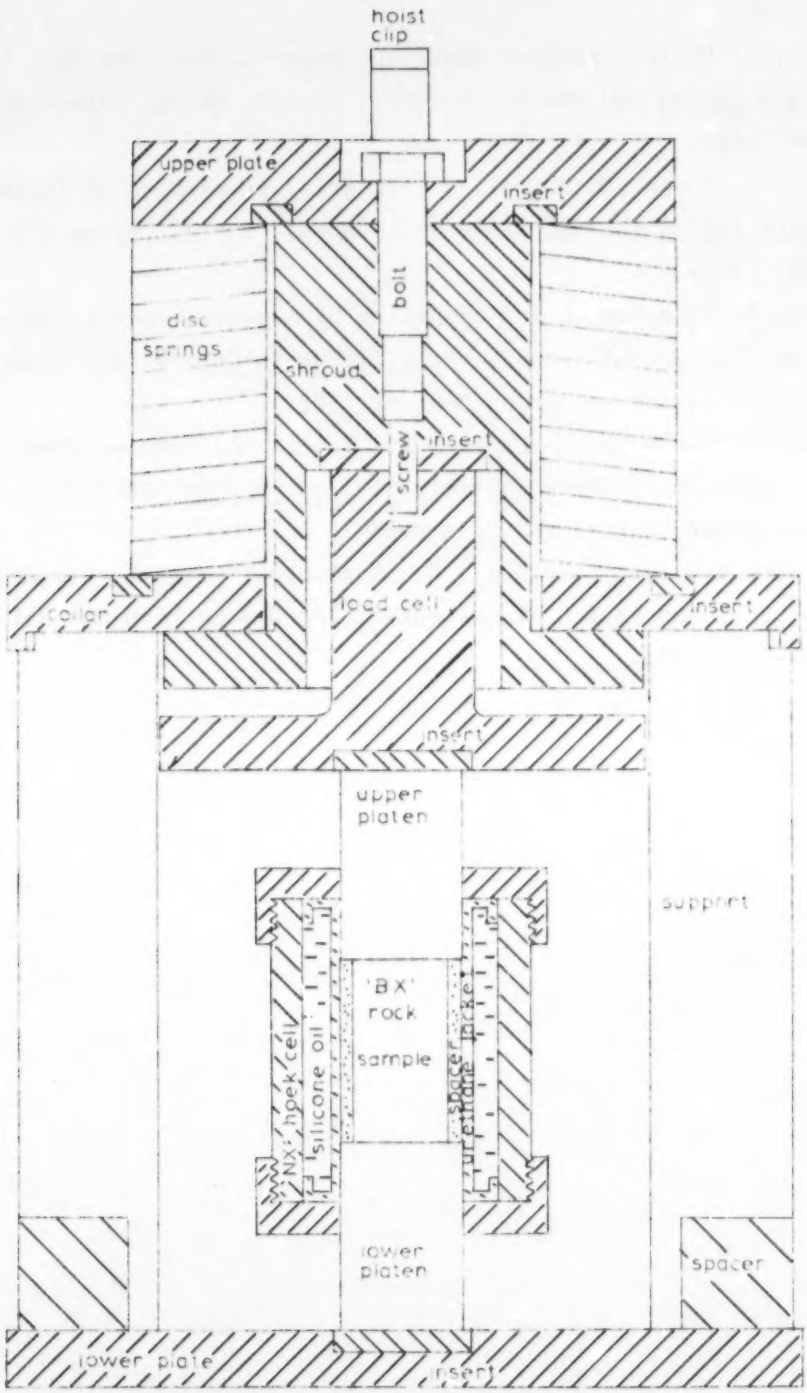

Fig.1 - Stiff assembly

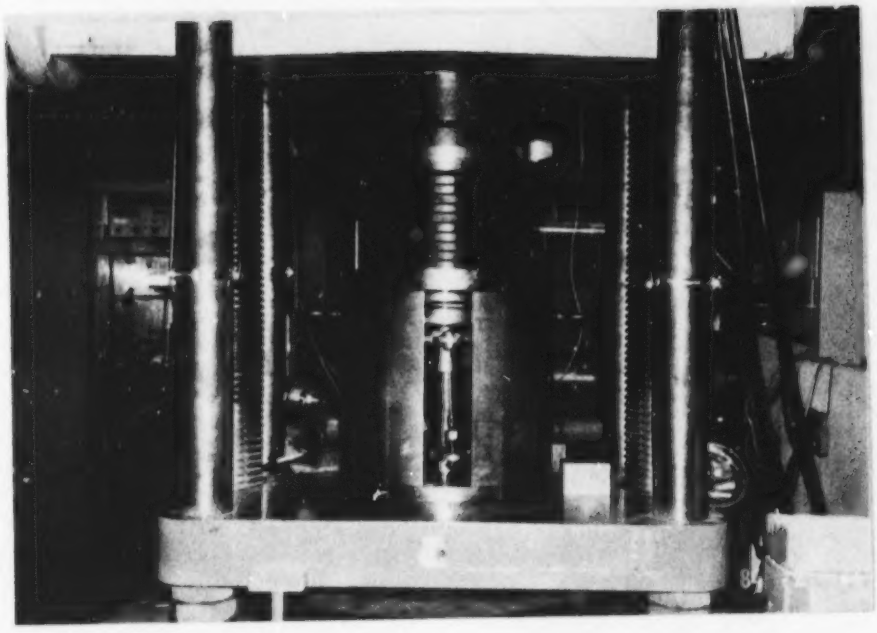

Fig.2- Stiff test set-up

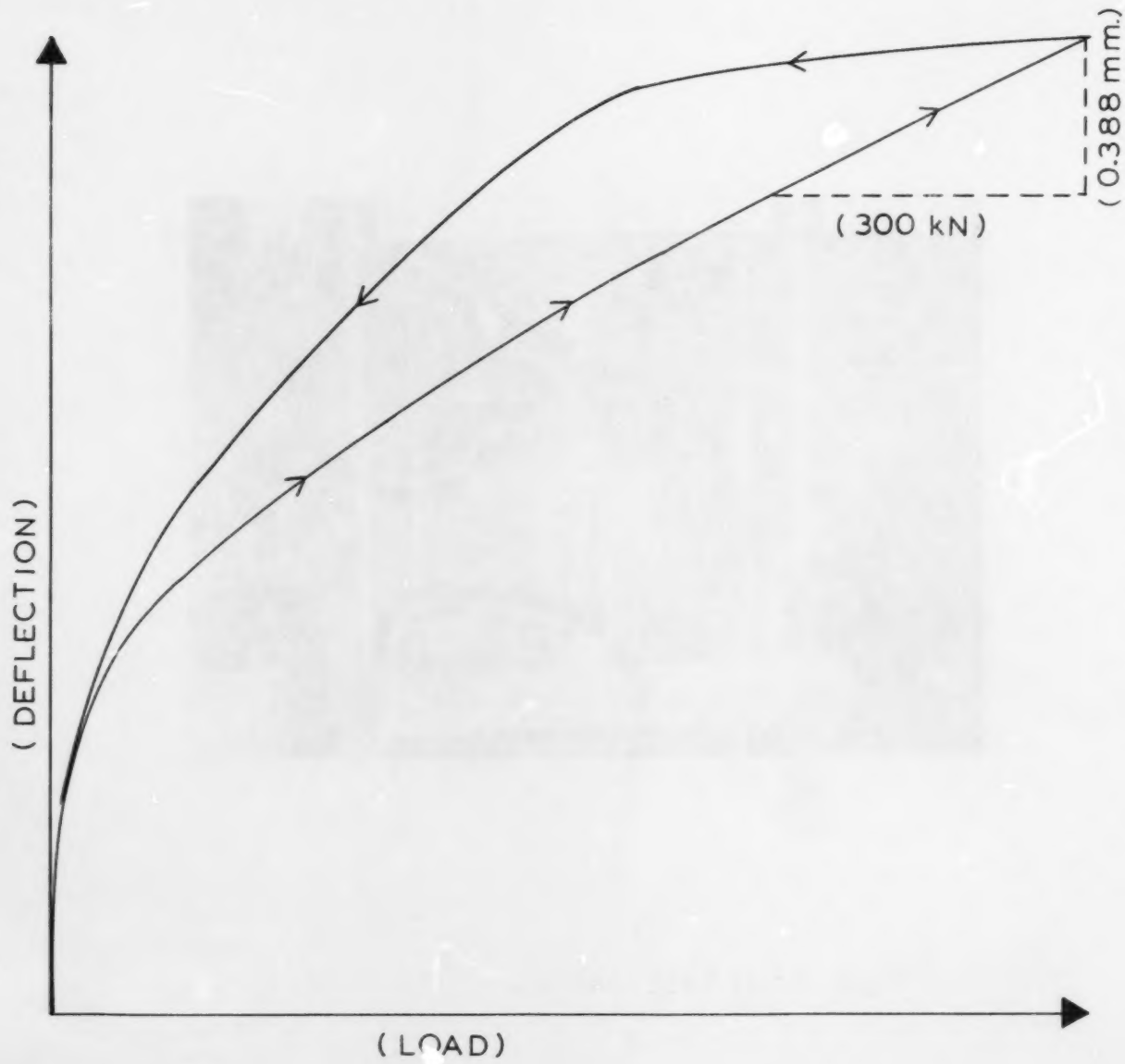

Fig.3-Assembly stiffness

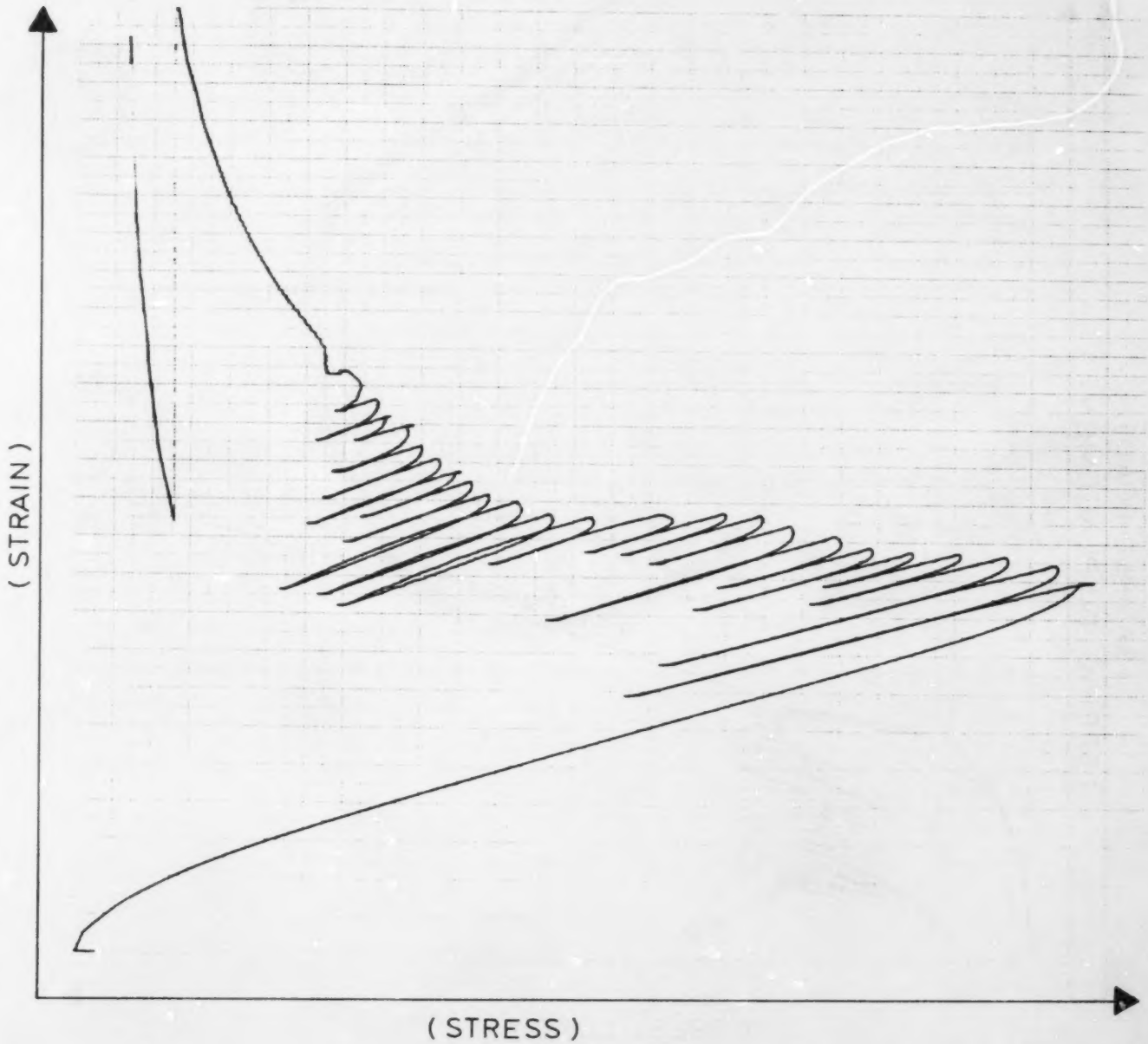

Fig.4 - Indiana limestone - uniaxial test

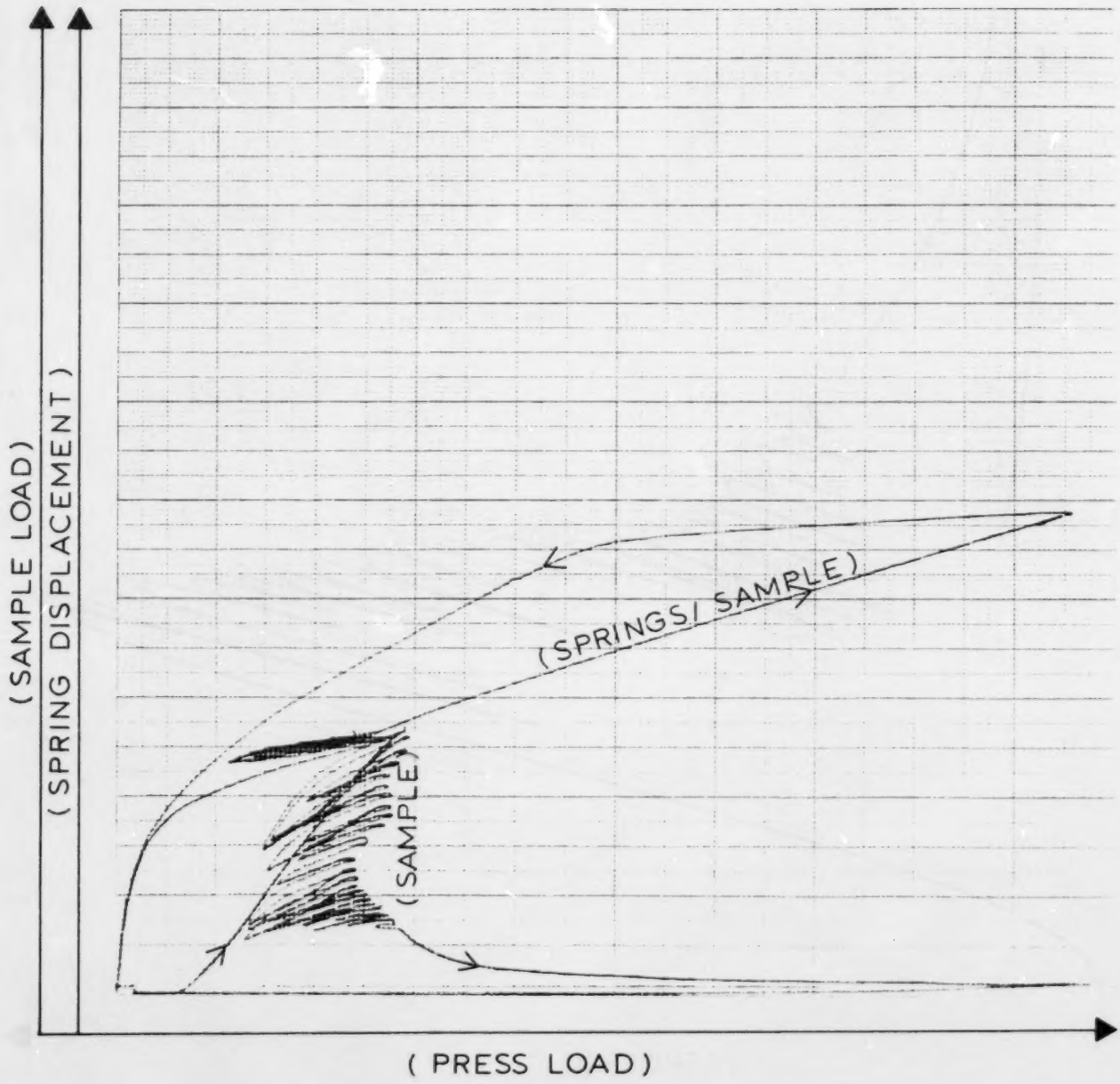

Fig. 5 - Spring/sample interaction